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PRODUCTIVITY AND COST OF PROCESSING FUELBARK IN MONTANA

Prepared for
MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

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PRODUCTIVITY AND COST OF PROCESSING FUELBARK
IN MONTANA

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Prepared for
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ABSTRACT

Bark must be comminuted to be acceptable for fuel. In-woods operations use whole-tree chippers because they are more versatile than knife or hammer hogs. Fixed-facility debarking operations require hogging.

The heat value of bark for three tree species common to western Montana was determined. The heat values ranged from 9,000 to 9,500 (BTUs) British thermal unit per bone-dry pound based on calorimetric testing of oven-dried samples. Although these values are slightly higher than figures published elsewhere, they are within the expected range.

Fuelbark production rates and costs (excluding raw material cost) were determined for the following operations:

OPERATION	HOURLY PRODUCTION BONE DRIED UNIT (BDU)	COST/ BDU (DOLLARS)
GREENOUGH LUMBER, INC.	0.52	11.24
SATELLITE CHIPPING	7.50	3.72
IN-WOODS		
Precommercial Thinning	2.9	7.30
Commercial Thinning	2.2	7.30
Multi-Product Operation	1.8	5.03
LUMBER MILL		
All Mills (average)	Not Available	1.92
Random Length Mills Only	Not Available	2.05

If a reliable market were available, fuelbark processing could be an economically viable operation. Reliable markets, in turn, will depend on the construction of co-generation facilities and biomass electric power generation plants. Inclusion of co-

generation capacity at existing lumber mills appears to be the most promising alternative at present.

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INTRODUCTION

Oil supply problems of the early 1970s stimulated the search for alternative energy sources. Recently, however, over-production of oil worldwide has discouraged the development of these sources. Oil production in the U.S. has decreased significantly because producing oil costs more than importing it. Although the U.S. controls only 4.6 percent of known oil reserves, it consumes 25 percent of world production. Consequently, oil imports have not only contributed greatly to the U.S. trade deficit, but U.S. dependence on foreign oil is once again growing rapidly. Lack of public confidence in nuclear power has contributed to this dependence on foreign oil. In short, the problem is similar to that of the 1970s--the public, lulled into complacency by the current oversupply of oil, is subject to the whim of foreign oil producers.

The threat of acid rain and the "greenhouse effect" are also renewing the need to investigate energy alternatives to oil and coal. Burning wood residues under the controlled conditions of an efficient boiler will produce far less impact on the environment than disposal burning or landfilling of these residues.

The burning efficiency of biomass fuel continues to improve, and this will lead to expanded industrial uses. Co-generation in lumber mills is currently restrained by two major problems. First, a large capital investment is required for the electric generating plant. Using second-hand equipment is an alternative with returns on investment possibly exceeding 30 percent. Second, the uncertainties of a stable long-term timber supply tend to shorten planning horizons. However, sawmills are examining the feasibility of co-generation to dispose of the growing supplies of mill residues (mostly bark). Co-generation will increase, despite public utility low buy-back rate. One sawmill discontinued planning for co-generation because the electrical buy-back rate allowed by the local utility and Public Service Commission was too low. The installation of biomass boilers at large facilities, such as institutions, schools, hospitals, and so forth, could help develop a reliable market. Montana State University has considered the feasibility of a wood-fired boiler plant. Experience in the northeastern United States clearly indicates that dependable sources of biomass can be developed.

Fuel Quality of Bark

Table 1 provides heat values per pound and per oven-dry ton of bark produced, as determined by bomb calorimeter tests for this project. The results of these tests are shown in Appendix A.

Table 1.

Bark Heat Values for Various Selected Pulpwood Species in Western Montana

SPECIES	MEAN BTUs/POUND	BTUs/TON
Bull Pine	9,313	18.6×10^6
Lodgepole Pine	9,540	19.1×10^6
Douglas Fir	9,058	18.1×10^6

Source: Appendix A.

The actual available heat value of bark will depend, in large part, on the moisture content. A bark moisture content of 60 to 100 percent, dry weight basis,[1] can be expected throughout the year. Logs or trees that have been cut more than two months prior to debarking will have lower moisture contents. Moisture contents will be much lower where pulpwood has been obtained from sawlog cleanup or salvage operations. For example, a small lodgepole pine tree will lose approximately 50 percent of its green moisture content if it is cut and left with the needles on for 14 days in the summer (Thayer 1979).

In-woods operations use chippers rather than hogs because they are more versatile. They can be used for pulp chips or fuel. Chipped bark does not require hogging and the chipping process removes much of the dirt. The end product of chipping is a versatile and high quality fuel compared to unchipped bark.

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[1] Dry weight basis is moisture weight/dry weight of wood x 100.

Historically, grit and dirt in the bark have been a serious drawback for fuelbark applications. Although improvements in burning technology have largely overcome the problem, this perception still persists. Chunky bark does not burn evenly, and suspension burning is inefficient. Therefore, hogging is necessary to improve fuelbark quality.

This report will examine various potential sources of fuelbark and energy wood, analyze production capabilities of the different operations, and then determine costs associated with the production. The sources include the following operations: (1) two pulp chipping plants, (2) in-woods chipping both from thinnings and multi-product logging, and (3) conventional sawmills.

In the determination of fuelbark production costs, it must be emphasized that not only is bark an unavoidable by-product, but it is also a nuisance in sawmill and plywood operations. This contrasts with a fuel production operation where bark is a component of the primary product.

When sawmills provided electrical power for their own needs and, in many instances, for the local community, hogged wood residues and sawdust were burned in the boiler plant. Excess residues went to the tepee burner. When bark-free wood residues became valuable for pulp chips after pulp and paper mills became established in the Northwest, planer shavings and sawdust became the favored fuel. However, as utilization technology improved, these sources of fuel became more valuable raw material for other processes--shavings to reconstituted board plants and sawdust to the pulp mills. In addition, concern over air quality led to the closure of the tepee burners. As a result, bark became the fuel of last resort because it had less value than wood residues.

Nevertheless, excess bark continued to accumulate at sawmills and plywood mills. Pulp plants then began to purchase fuelbark to reduce mill inventories. Presently, the pulp mills attempt to utilize between 60 and 80 percent of the bark produced by their pulp chip suppliers. However, bark inventories are growing and are becoming an increasingly costly nuisance with a real potential for becoming a serious hazard. In 1988, for example, one sawmill purchased 70 acres just for bark storage. Another sawmill is using two full-time employees and a front-end loader to suppress a bark pile fire that has been burning for seven months. Yet another sawmill operator is seriously considering electric power generation as a means of reducing bark accumulation. Although the current oil glut has curtailed progress somewhat, the technology of efficiently burning fuelbark has been developed.

This background information is critical to the approach used for determining fuelbark production costs. Cost determination can be based on the assumption that debarking is a necessary cost of producing lumber and/or plywood. Conversely, fuelbark production could be considered a separate cost center in which revenue and expenses are allocated by specific management rationale.[2]

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[2] Generally, sawmills do not monitor the volume or cost of bark production, and it is not considered a production component.

GREENOUGH PULPWOOD CHIPPING OPERATION

The Greenough Lumber, Inc., plant was originally designed to produce two-sided houselogs for a Missoula manufacturer. The mill was also capable of producing rough lumber. However, the houselog market disappeared, and the new owners attempted to run the facility with a minimum of working capital solely as a lumber mill. A joint study of fuelbark production was proposed by Greenough Lumber and partially financed by the Montana DNRC. This study was intended to document production volumes and costs of recovering fuelbark from a small sawmill. At the time of the study, the facility was being operated temporarily as a pulp chip plant while additional financing was sought. It is important to note that the facility, as described below, is not as efficient as a mill designed specifically for chip production.

Debarking-Chipping Operation

Bark in pulp chips causes problems in the pulping process and lowers the pulp quality. Therefore, debarking is a necessary part of the pulp chipping process.

Raw Material

Pulpwood was delivered in tree lengths rarely exceeding 50 feet to a minimum 3-inch top diameter, inside bark (dib). The material was decked for storage or fed directly to the bucking saw.

Pulp chips are considered a by-product in a sawmill or plywood operation. They have a relatively low value compared to the primary product. Likewise, pulpwood, or chip logs, have a low value. As expected, pulpwood is usually poor quality timber not desired as raw material by the sawmills. Pulpwood most often consists of trees of small diameter, contains excessive crook or sweep, or is an undesirable species. However, for forest management activities, a pulpwood chipping operation does provide a market for thinnings and logging residue.

Lumber markets dictate species preference for sawlogs, and they can vary by season of the year and by sawmill operator. For example, there is very little demand for bull pine (young, limby ponderosa pine). The preferred species is lodgepole pine smaller than 12 inches in diameter breast high (4.5 feet from the ground). Lodgepole pine, because of its straightness and lack of taper, is also a desirable species for chipping. Large whole log chippers can process several pieces at one time. The local market, Stone Container Corporation, will not accept cedar or hardwood chips. It also does not want chips from dead logs because the material deteriorates in storage.

As a rule, the only economical method for measuring small diameter logs is by weight--the material is purchased on a green-ton basis. Greenough Lumber did not have a scale, so an individual deck of logs was maintained for each supplier. The decks were processed separately and the chips hauled to market. Stone Container measured the loads and paid the Greenough mill, which in turn paid the appropriate supplier. Working capital requirements for Greenough Lumber were radically reduced because it did not have to pay inventory costs for the raw material.

In summary, Greenough Lumber processed low quality logs that ranged from a minimum dib of 3 inches to a maximum dib of 10 inches. Species volume consisted of 70 percent lodgepole pine, 20 percent bull pine, 5 percent Douglas fir, and 5 percent other species. Incoming raw material was segregated according to supplier. Chips manufactured from these decks were the basis of payment for each supplier.

Bucking and Debarking Process

Although it would have been much more efficient to handle the material without cutting the tree-length logs into shorter pieces, they were cut because: (1) the front end of the log had to be square for the debarker to function properly; (2) the outfeed conveyor of the debarker accepted lengths of only 18 feet and shorter; and (3) the chipper, designed for sawmill slabs, could only process logs 10 inches and smaller in diameter. (Trim butt ends were sold as firewood.) These size limitations caused serious inefficiencies in the entire process. In normal chipping operations, bucking is needed only to reduce excessive crook and sweep in a tree-length piece.

A used 21-inch capacity Cambio ring debarker was used to debark the bucked logs. To facilitate pulpwood transport to the chipper, a log kicker was installed behind the debarker. This device pushed the debarked logs into a bunk where they could be moved with a forklift. Stone Container was also the market for fuelbark, and it required that the bark be hogged (ground up into small pieces). To satisfy this requirement, a small knife hog was installed off the debarker. Bark was first conveyed from the debarker to the hog. From the hog it went into a conveyor that allowed loading directly into a truck or open-top trailer, or it could be piled on the ground for reloading.

Pulp Chipping Process

The chipping procedure is included in this discussion to facilitate comparison with the other operations.

A forklift was used to move the debarked logs to a table that led into the in-feed conveyor of the chipper. The 140-horsepower forklift was oversized for this operation because it was also used for unloading trucks and handling material in the log yard. The logs were rolled onto the chipper in-feed conveyor by hand. Oversized pieces were removed to the firewood site at this point. Chips were blown into a 24-unit storage bin.

Labor Requirements

The operation required three workers plus a millwright. A description of their duties follows.

> The forklift "loader" operator unloaded incoming log trucks, decked the tree-length material, fed the in-feed conveyor to the bucking saw and debarker, and transferred peeled logs to the chipper in-feed. He also used a large bucket, constructed for the forklift,

to pile bark when necessary. On occasion he loaded trucks with the forklift and bucket attachment.

The bucking saw operator cut tree-length pieces to proper length, trimmed oversized butt ends, and monitored the debarker operation.

The chipper operator fed material into the chipper in-feed conveyor.

Machinery Requirements

The millwright performed maintenance and repair work throughout the entire facility, and also supervised the crew.

The machinery used in the debarking-chipping operation sand their respective power requirements are listed below:

Equipment	Power Requirements - Horsepower
Forklift	140.00
Log Deck and Buck Saw	38.75
Debarker and Conveyor	62.50
Bark Conveyor and Hog	14.00
Chipper and Bin	208.00
Shop	2.50
TOTAL	465.75

BARK PRODUCTION

A precise measurement of bark production from a log debarker is difficult, if not impossible. During removal, pieces of bark are thrown in all directions, and it is extremely dangerous to collect all the material. Prudent mill owners would prohibit such collection. Consequently, it is necessary to determine the volume of bark produced by indirect means.

Bark-Volume Determination

Meyer (1946) developed a ratio of dib and diameter-outside-bark (dob) by comparing double bark thicknesses at different diameters throughout the length of a tree. This was a comparison of the cross-sectional areas of bark and wood. However, in his calculations, he did not compensate for the roughness or fissures in the bark. Chamberlain and Meyer (1950) used a similar procedure on smaller diameter trees, which is more applicable for bark determination for pulpwood-sized material.

Krier and River (1968) refined this procedure by considering bark roughness on sawlogs in Montana. They determined that the cross-sectional area of the bark should be reduced by 26 to 28 percent. For the 9-inch-diameter class of sawlogs, they calculated the following:

SPECIES	CUBIC FEET OF BARK per MBF Log Scale	CUBIC FEET OF BARK per ft^3 Wood	CROSS SECTION VOID Percentage	BARK VOLUME Percentage of Wood
Ponderosa Pine	51.2	.234	26	17.8
Douglas Fir	60.3	.252	27	18.4
Western Larch	41.8	.213	28	15.3

Using the above listed values, the bark volumes can be estimated.

Faurot (1977) has determined gross bark volumes for a broad range of tree sizes, including typical pulpwood-sized material. It is necessary to adjust his results because he does not allow for voids in the circular cross-section of bark.

Standard Production

Samples were taken from log decks prior to debarking to determine a standard log size for the Greenough Lumber operation. Faurot's tables, adjusted for bark voids, were used to estimate the bark volume for this standard-sized log. Bark production was then determined for different throughput rates at the debarker.

Table 1 illustrates the derivation of bark volume recovered from a standard log through the debarker. The standard log contains 0.63 cubic feet of bark. The average log has 1.96 pieces, each one 18 feet long. Each piece in turn contains 0.32 cubic feet cubic feet of bark.[3] Summary descriptors for the standard log are:

Bark volume, each log	0.63 cubic feet
Number of 18-foot pieces, each log	1.96
Bark volume, each piece	0.32 cubic feet
Bark volume per lineal foot	0.18 cubic feet

---

[3] due to bulk volume expansion of solid tight bark, one cubic foot of bark on a log equals 2.23 to 2.35 cubic feet of loose bark.

Table 2.

Bark Volume Determination

Butt Diam (in.) (1)	Length (ft.) (2)	Component (%) (3)	Bark Void Ratio (4)	Bark Gross (ft^3) (5)	Volume Net (ft^3) (6)	Wghtd. Volume (ft^3) (7)
LODGEPOLE PINE (LPP) - 70% Total Vol; No. Pc/Tree 2.24						
9	43	65	.14	.60	.52	0.34
7	36	30	--	.42	.36	0.11
5	32	5	--	.26	.22	0.01
						.46
BULL PINE (BP) - 20% Total Vol; No. Pc/Tree 1.46						
9	29	75	.21	1.80	1.42	1.07
7	18	25	--	1.09	0.96	0.22
						1.29
DOUGLAS FIR (DF) - 5% Total Vol; No. Pc/Tree 1.98						
9	37	60	.18	1.38	1.13	0.58
7	34	35		.87	.71	0.25
5	28	5		.47	.39	0.02
						0.85

OTHER SPECIES - 5% Total Volume

USE MEAN VOLUME for above species.

Standard bark volume per piece^3 gross volume.
*.70 (LPP) + .20 (BP) + .05 (DF) = + other species
0.32 + 0.26 + 0.04 + 0.01 = 0.63 ft^3/Pc, net bark volume

Bark production can be estimated by using debarker throughput rates times the various standard log descriptors. However, it should be noted that actual production rates at Greenough Lumber are unsatisfactory for two major reasons.

1. Bucking saw production determined the piece rate for the debarker. All too often delays occurred for reasons unrelated to the debarker--for example, crooked logs in the saw in-feed chute, forklift doing other tasks, or shortage of logs for the bucking saw.
2. The debarker did not function properly on large diameter logs because of excessive knife pressure. The debarker did not have automatic or variable pressure controls and was designed for sawlogs, not pulpwood. As a result, when the pressure was set to adequately debark small logs, the pressure was too high for the larger sizes.

A series of time studies were conducted on the debarker at Greenough to determine different production levels for an average throughput rate. When delays and downtime are excluded, the debarker throughput rate ranged from 58.2 to 66.3 lineal feet per minute. The average rate was 62.0 feet per minute. This rate is considerably slower than that experienced by other mills that have similar debarkers, where production rates of 100 to 125 lineal feet per minute for pulpwood are common. The poor condition of the Greenough debarker and lack of pressure control were the major causes of the low rate.

Table 3 lists bark volume production in cubic feet per hour by different in-feed rates and piece sizes. Although the figures in table 3 are based on 100 percent operating efficiency, this operating level cannot be met because of gaps between the pieces, and conveyor hang-ups do occur.

Table 3.

Bark Production Volume for Varying Piece Volume and Throughput Rates

Vol/ Lineal Foot[a] (ft^3)	Debarker Feed Rate - Lin. ft/min. 50	80	110	140
	Cubic Feet Per Hour[b]			
.010	30	48	66	84
.015	45	72	99	126
.020	60	96	132	168
.025	75	120	165	210
.030	90	144	198	252
.035	105	168	231	294
.040	120	192	264	336
.045	135	216	297	378
.050	150	240	330	420

[a] Cubic feet of bark volume per lineal foot of piece going into the debarker.

[b] Volume of solid bark, not compensated for loosened bulk density which would be 2.25-2.35 times more.

Table 4 lists the output from table 3 in terms of tons per hour. An average bark density of 30.0 pounds per cubic foot is used for converting cubic feet to tons.

Table 4.

Bark Production--Tons Per Hour

Vol/ Lineal Foot[a] (ft^3)	Debarker Feed Rate - Lin. ft/min.[b]			
	50	80	110	140
	Tons Per Hour[c] - Bone Dry			
.016	0.72	1.15	1.58	2.02
.017	0.77	1.22	1.68	2.14
.018	0.81	1.30	1.78	2.27
.019	0.86	1.37	1.88	2.39
.020	0.90	1.44	1.98	2.52
.022	0.99	1.58	2.18	2.77
.024	1.08	1.73	2.38	3.02
.026	1.17	1.87	2.57	3.28
.028	1.26	2.02	2.77	3.53
.030	1.35	2.16	2.97	3.78

[a] Bark volume per lineal foot of piece going into debarker.

[b] Assumes a 60-minute hour.

[c] Bark density = 30.0 pounds per cubic foot (#/ft^3) as an average figure. Specific density of bark can vary for species, diameter, and position in tree. For example:

Ponderosa Pine = 29.34 #/ft^3
Bull Pine = 30.86 #/ft^3
Western Larch = 21.84 #/ft^3
Douglas Fir = 29.95 #/ft^3
Lodgepole Pine = 29.17 #/ft^3

Energy Content

Table 4 can be converted to energy content (heat availability) by multiplying the weights times the BTUs per pound of bark for various species by using table 1. In-deck sampling at the Greenough log yard yielded bark moisture contents from 7 to 28 percent.[4] Higher amounts of moisture in the bark will reduce the amount of heat available when converting to energy. This is due to the amount of energy absorbed by the water liquid to water vapor process.

Bark Production

The previous tables can be used to estimate bark production for the Greenough Lumber, Inc., operation. From table 2 the standard log contains 0.62 cubic feet, or 0.018 cubic feet per lineal foot of log length.[5] At a debarker feed rate of 62.0 feet per minute and from interpolation in table 3, the mill produced 58.0 cubic feet, or 1.01 tons per hour.

This theoretical maximum production volume should be reduced to reflect the serious operating problems mentioned previously. The debarking operation normally operated at approximately 68 percent efficiency, excluding extraneous factors, such as the lack of raw material. The actual average bark production rate of the debarker was about 39.4 cubic feet or 0.63 tons per hour.

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[4] The upper limit moisture content was 28 percent, the assumed fiber saturation level and the top limit of the moisture meter.

[5] Due to tree taper, there will be a small difference in bark volume between the butt and top of the tree. However, the average bark volume for the entire usable log was determined prior to segmenting it into 18-foot pieces.

PRODUCTION COST DETERMINATION

For the Greenough Lumber example, the production of fuelbark is considered a necessary cost of producing the primary product, pulp chips. Using this approach, the fuelbark process begins at the debarker out-feed conveyor and ends at the fuel storage facility. Table 5 indicates the process of determining labor and other costs for processing fuelbark in Greenough's operation.

Raw Material Cost

In the forest products industry the cost of raw materials is that of the major ingredient used in the manufacturing process--namely logs, including bark. Because the mills manufacture products only from the woody portion of the log, the raw material cost of bark is really zero--an assumption that will be used in this economic analysis.

Labor Cost

Since bark processing and handling are not specific functions of the pulp chipping process, fuelbark costs can be considered as separate from chipping. Hence, only incremental costs will be charged to fuelbark.

At the Greenough Lumber site only two employees--the forklift loader operator and millwright--were directly involved in processing and handling fuelbark. The hourly base wage with 27 percent payroll overhead (OH) for each of these employees is:

Forklift Loader Operator	$5.00/hr.	+	27% OH =	$ 6.35
Millwright	$8.00/hr.	+	27% OH =	$10.16

The primary responsibility of the loader operator was to keep the debarker and chipper supplied with material. Handling bark was a part-time responsibility. Using a large bucket on the forklift, the operator can accomplish this task in about 1/2 hour each shift. This converts to 63 cents per ton of bark.

The millwright spent about 6 hours per 5 shifts maintaining and servicing the hog and bark conveyors. The hog work was primarily sharpening the knives and cleaning the hog if it plugged up. The conveyor work was mainly lubricating. The millwright labor charge at $10.16 per hour amounts to $2.42 per ton.

Machine Cost

As mentioned previously, a 140-horsepower forklift-loader was used throughout the operation. The operating cost of the loader, excluding wages, was $8.72 per hour. This rate appears to be very low. It was purchased used at a reasonable price, and a machine cost accounting system had not been set up to reliably determine the repair costs. As illustrated in table 5, it amounts to 87 cents per ton of bark handled.

The hog and bark conveyors use a total electric horsepower rating of 14.0 horsepower. This amounts to 4 percent of the total electric horsepower rating for the entire pulp chipping operation. Hence, it is reasonable to charge the electric power cost at the rate of 1.9 cents per kilowatt hour (KWH), the rate for usage over the minimum demand. Since one horsepower equals 0.75 KW, the electrical consumption is 10.5 KW per hour of operation. This amounts to 20 cents per hour for electrical power. At 0.63 tons per hour bark production, this sets the cost of electricity at 32 cents per ton.

Maintenance Supplies

An amount of $1.23 per hour has been set as the cost of maintenance supplies. This consists mainly of hog knives and lube materials. The $1.23 per hour cost converts to $1.95 per ton of fuelbark processed.

Depreciation

Depreciation of the hog is based on 6,000 hours, which sets an hourly charge of 75 cents. The conveyors are charged depreciation over 10,000 hours for an hourly charge of $1.26. Total depreciation is $2.01 per hour or $3.19 per ton of fuelbark.

Summary

The total processing cost is $9.37 per ton. This amounts to $11.24 per BDU at 2,400 pounds. Fuelbark sold for $6.00 per BDU. This presents a deficit of $5.24 per BDU produced.

The Greenough Lumber case study was undertaken with the caveat that it was not an economically feasible operation. As mentioned previously, the facility was not originally designed to chip pulpwood as the primary product. To obtain a more realistic and accurate assessment of fuelbark production economics, it is useful to examine three other alternatives for producing fuelbark or fuel wood. They are a satellite chipping plant, in-woods production systems, and conventional sawmills. In all cases, direct cost data from existing operations were not used, but indirect means were used to develop the information. New machinery prices, either purchased off-the-shelf or installed on a turnkey basis, were used to determine acquisition and installation costs. Operating costs were developed using various standard, industry-accepted procedures. Discussions with mill owners and logging contractors verified these theoretical costs.

Table 5.

Greenough's Cost of Processing and Handling Bark

ITEM	COST $/Ton
Electric Power	0.317
Labor	3.050
Loader	0.865
Maintenance	1.952
Depreciation	3.186
	$9.37 Ton = $11.24/BDU @ 2400#

LABOR

Loader 1 hr/16 hr = 1($6.35)/16(.63 T/hr) = 0.630/T

Millwr. 6 hr/40 hr = 6($10.16)/40(.63 T/hr) = $2.420/T

$3.050

LOADER 1 hr/16 hr = 1($8.72)/16(.63T/hr) = $0.865/T

MAINTENANCE & SUPPLIES $\frac{\$1.23/hr}{.63T/hr}$ = $1.952/T

DEPRECIATION

Conveyor $12,570/10,000 hr = $1.257

Hog $ 4,500/ 6,000 hr = 0.750

$2.007/hr

$\frac{\$2.007/hr}{.63T/hr}$ = $3.186/T

SATELLITE CHIPPING OPERATION

RAW MATERIAL

A satellite chip plant purchases primarily nonmarketable sawlogs and small trees that sawmills and plywood mills cannot use or do not want. Although this material is small, cull, or of poor quality, it requires only minimal handling in a normal logging operation. Secondarily, the mills may also buy spinouts and nonchuckable plywood bolts that cannot be processed by a studmill. Usually these plywood plant rejects are larger than usual pulp trees.

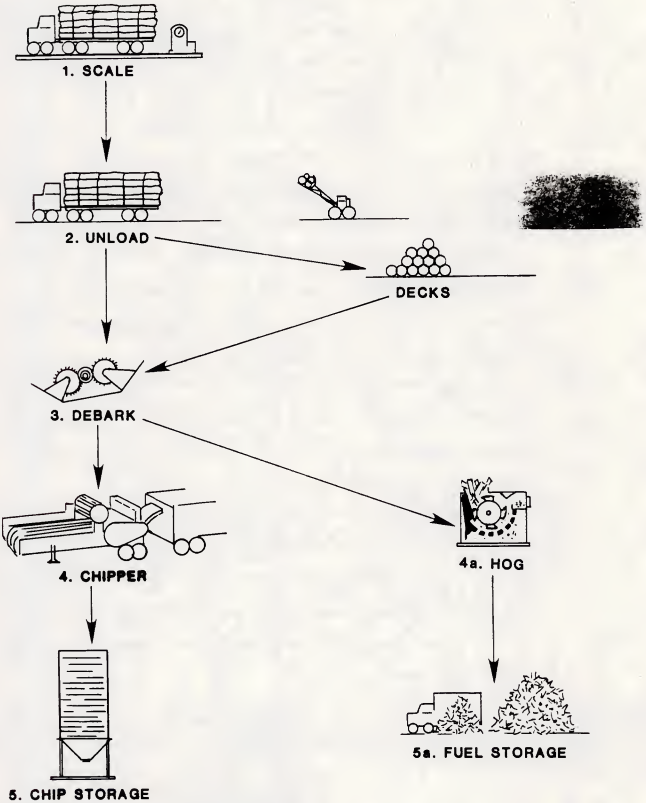
Because species, diameters, and input volume vary considerably, it is difficult to determine a bark-to-wood ratio that would be applicable throughout the entire year. However, over time, fuel volumes should be approximately 11 to 15 percent of wood chip volume. In addition, about one percent of the total raw material input to the plant becomes waste through breakage or mismanufacture, and this is added to the fuelbark volume. A 15 percent bark-to-wood ratio will be used in this analysis.

PRODUCTION PROCESS

The chipping process is a continuous flow system. Lack of material to the debarker is the major cause of reduced productivity. Figure 1 illustrates the schematic flow of material through a typical facility. The numbers in the process flow diagram refer to the paragraph numbers in the text that explain the diagram items. 4A and 5A are used for processing fuelbark.

FIGURE 1

PULP CHIPPING PROCESS FLOW DIAGRAM



A narrative description of each step in the process follows.

1. Incoming loaded trucks are first weighed at the plant entrance and then weighed again after unloading to determine the net weight of raw material. Material specifications are a 4-inch minimum top dib and an 18-inch maximum large end dib. The minimum length is 12 feet and the maximum length is 52 feet.[6] Normal sawlog defects, such as crook, sweep, limb stubs, and improper lengths, are acceptable. Payment for material that would normally be culled at a sawmill is beneficial to both the logger and the chip plant. The loggers' costs are reduced, and they can generate much of the material by just sorting at the landing. In turn, loggers are more willing to supply logs when they receive full payment with no docking.
2. A 200-horsepower forklift unloads the truck in 12 to 15 minutes. The logs can be placed directly on the in-feed deck of the debarker, or, if this is full, the logs are piled into storage decks.
3. An operator uses a hydraulic loader to place the logs on the in-feed chute of the debarker. The debarker removes the bark without bucking the log or tree lengths at the rate of 150 to 250 lineal feet per minute. Debarker speed is the key to production--the logs can't be chipped if they are not first debarked.

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[6] The maximum log length depends on the design configuration of the log truck and pertinent highway regulations.

4. The chipper feed rate is automatically determined by the rotational speed of the chipping disk. To prevent system bottlenecks and maximize efficiency, the chipper capacity should exceed that of the debarker. Because chips from whole logs are usually better quality than chips from mill residue, a screen is not absolutely necessary. The chipper removes most of the fines, which improves chip quality and also increases the fuel component.

4a. Bark removed at the debarker is conveyed to the hog, where it is comminuted to improve its fuel characteristics. Primarily, the large chunks are ground into smaller pieces, a requirement of the fuelbark market.

5. Chip storage consists of accumulating the material into van-load quantities. Normally the chips are conveyed or blown into elevated bins for subsequent loading into open-top vans. A few operations dump the chips directly into a parked van or onto the ground. Although these two options reduce the investment in chip handling facilities, they do require extra vans or a method of reloading the ground-stored chips. This analysis assumes use of a conventional chip bin.

5a. Because the fuelbark market is not as profitable or reliable as the chip market, most mills will not make the capital investment for storage bins. Fuelbark is often stored in chip trailers or on the ground and then hauled at a later date. Sawmills and plywood plants produce a surplus of bark, so it is stored in piles and hauled as market conditions permit. Storage in a parked van will be the method used in this study.

PRODUCTION COST DETERMINATION

For purposes of analysis, the operation produces 50 bone-dry units (BDU) of chips per hour or 400 BDU per eight-hour shift. A bone dry unit is 2,400 pounds of bone dry material. Annual production is 88,000 BDU (220 working days per year).

With a bark-to-wood recovery ratio of 15 percent, 7.5 BDU units of bark are produced hourly.[7] Using an average annual moisture content of 40 percent, a BDU of green bark weighs 3,360 pounds or 1.68 tons. Table 6 presents the basis for determining the incremental cost for processing fuelbark.

Raw Material

It could be argued that chip production should carry the total cost of raw materials, including bark. Chips have a predictable volume and market price; therefore, it is easy to estimate total chip production costs reliably. With the current uncertainties in the market, it would be realistic to ignore bark as a product and assign it no raw material cost.

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[7] Although there is a shrinkage factor of 0.75 percent, this amount is minor and will not be included in the calculations. Including the shrinkage factor would imply a degree of preciseness in the analysis that is neither warranted nor intended.

Table 6.

Fuelbark Cost Basis--Satellite Pulp Chipping Operation

		HOURLY COST		
ITEM	PRICE	Fixed	Variable	Total
HOG	$65,000	$10.25	$9.90	$20.15
CONVEYORS	38,000	2.16	1.10	3.26
ELECTRIC POWER			.67	0.67
LABOR			3.85	3.85
				$27.93/Hr
				$ 3.72/BDU

Fuelbark production rate = 7.5 BDU/hour
Selling price = $5.26/BDU

No trailer cost. It is absorbed in hauling and fuel price determination.

Labor

The only labor directly involved occurs when the trailer being loaded has to be moved to even the load. This work is done on a debarker time basis. The operator feeding the debarker infeed moves the trailer as needed. He does this without interrupting the debarker operation. Through an 8-hour shift, this totals 150 minutes or 19 minutes. At a total wage cost of $12.82 per hour, this amounts to an hourly charge of $3.85 against fuelbark.

Summary

Other cost items are shown in table 6. There is a total hourly cost of $27.93, which converts to $3.72 per BDU at a production rate of 7.5 BDU per hour. A profit of $1.54 per BDU is attained from a selling price of $5.26 per BDU. This cost determination has considered the incremental cost of processing bark. That is, the cost of capital and operation only involved in processing bark have been considered. This pertains to hog, conveyors, and labor. The other part of the operation deals with processing pulp chips. This cost determination has considered the incremental cost of processing bark. That is, the cost of capital and operation only involved in processing bark have been considered. This pertains to hog, conveyors, and labor. The other part of the operation deals with processing pulp chips.

IN-WOODS FUEL OPERATIONS

Any in-woods fuel recovery operation is a marginal undertaking. Among the several factors that affect this marginality, the most critical are market availability and price. Although these criteria are important in any logging operation, they are particularly crucial to in-woods fuel processing for two reasons. First, in many instances, a market for the product is available for only certain periods of the year. Second, product value is often arbitrary because fuel market inventories can be readily adjusted through price--supply is very price-elastic. Installation of wood-fired power plants could dramatically reduce these uncertainties by establishing a reliable market and price structure.

The two most important operational factors for successful in-woods fuel production are tree size and processing costs. Once again, both are interdependent in conventional logging operations--larger trees have lower logging costs, and smaller trees cost more to process. Fuelwood operations process small material, so costs tend to be high.

PRODUCTION PROCESS

Unlike the previously described fixed plant facilities that produce fuelbark, the in-woods operations produce a fuel comprised of bark, wood, branches and needles or leaves. Raw material can originate from thinnings or from residue left in an integrated logging operation. The raw material is processed by a whole-tree chipper. These units vary in size, and some can process full trees up to 27 inches in diameter. In general, producing fuel chips as part of an integrated logging system is the most economically feasible approach. However, a number of contractors have used thinnings, and this method is viable under strong market conditions.

Thinning Operations

Thinning is a silvicultural tool used by forest managers to control tree density or spacing in a forest stand. Some trees are cut so that the total growth potential of the site is concentrated on fewer stems that will grow to marketable size in a shorter time. There are two types of thinning--precommercial and commercial. By definition a precommercial thinning is an operation that produces little or no immediate revenue. By contrast, a commercial thinning implies that revenue equals or exceeds costs. Obviously, these terms are rather arbitrary, and what may be called a precommercial thinning by one operator is a revenue-producing operation for another. Stand area, topography, stem size, tree species, harvesting system, and market conditions all interact to differentiate precommercial from commercial thinning.

As stated, forest managers will precommercially thin a stand to improve growth on the residual trees and thereby increase future revenue. Often a thinned stand is also less susceptible to damage from insects and disease. Many landowners will log when stumpage prices are high and invest some profits in thinning for long-term forest improvement. Landowners may also be eligible for federal cost-sharing programs, such as the Agricultural Conservation Program (ACP) of the Agricultural Stabilization Service. Current cost-sharing allowances are $2.46 for each square foot of basal area removed to a maximum of $138.00 per acre. These costs can help defray the cost of precommercial thinning.

Traditionally, precommercial thinnings were either left in the woods or piled and burned. However, spurred by the renewed interest in fuel wood brought about by the oil crisis in the mid-1970s, efforts were made to recover this material. Numerous studies and tests were conducted in the Blackfoot River valley of western Montana to develop techniques for harvesting and processing small trees for fuel (Goetz 1980, 1982, 1987; Host and Lowery 1970, 1983; Mandzak, Milner and Host 1983). Goetz, who directed or monitored much of the work, suggests three criteria necessary for successful processing of small trees:

1. The operator must have accurate stand data to determine the size and number of trees to be removed.
2. A coordinated, well-planned logging system is needed.
3. The system must be matched to the timber size.

One of the Blackfoot studies compared the cost of producing full-tree fuel chips using two readily available commercial chippers. The units could process a tree (or group of smaller trees) with a diameter of 12 and 22 inches, respectively. The results were as follows:

	PRODUCTION IN TONS PER HOUR	
Tree Diameter	Morbark Model 12	Morbark Model 22
Less than 5 inches	10.44	14.85
5 to 11.5 inches	14.53	16.21

Although the smaller machines produced slightly less than the bigger unit, the Model 12 was less expensive, more portable, and had lower operating costs (Goetz 1980). It could also produce fuel chips at a somewhat lower cost per ton.

Several studies (Brown, S. L. and J. A. Bergvall 1986; Goetz, H. 1982; Host, J. R. and D. P. Lowery 1970; Lambert, M. B. and J. O. Howard 1987) have shown that maintaining a supply of trees to the chipper is extremely important for the operation to be economically feasible. It is necessary to match machine chipping capacity with feeding capability and vice versa. Because smaller trees can be processed so quickly, maintaining a constant supply is difficult. When terrain permits, this problem can be alleviated by stockpiling the material at the landing prior to chipping (Goetz 1982).

The production of fuel chips in a commercial thinning operation is similar to that in precommercial thinning. The major difference is that the trees are bigger, and larger harvesting/processing machinery can be used effectively and economically.

Multi-Product Logging Operations

Multi-product logging differs from conventional logging in that the latter deals only with sawlog-sized materials. A multi-product operation will process a variety of material based on the potential product. Posts, poles, houselogs, pulp chips, and/or fuel may be recovered in addition to sawlogs. Because this report concerns sources of fuel, only the production of sawlogs and fuel will be considered.

In multi-product logging the whole tree, less stump, is skidded to the landing. Trees can be limbed and bucked more efficiently, safely, and at less cost on the landing than at the stump. However, processing entire trees at the landing does result in large concentrations of slash. As a result, some landowners prohibit this method for aesthetic reasons and because of potential fire and insect hazards. If fuel markets were readily available, processing the residue into fuel would alleviate these concerns.

Some foresters feel that removing the tops and limbs from the woods may result in long-term soil nutrient deficiencies (Laird 1988). A few even suggest that landing residue be hauled back to the harvest site--a very costly process at best. Some land managers presume that whole tree removal will not result in soil nutrient deficiencies on most forested land. They believe that normal leaf cast and the natural recycling of understory vegetation are adequate nutrient sources. However, the potential adverse effects of slash removal must be considered on a case-by-case basis.

The material processed in multi-product logging is dependent largely on the utilization standards applicable to each operation. The sizes and volumes of residues are very site specific. For example, a thinning operation in an immature stand will bring in trees usually less than 8 inches dbh. By contrast, large trees averaging 12 to 13 inches dbh are cut in conventional operations. This relatively small difference in tree size can result in a wide range of volumes (and values) of residue.

PRODUCTION RATES

Average production rates for the extraction and processing phases will be used as the basis for production costs. It should be noted that production rates will vary depending on operator experience, logging system efficiency, and timber stand characteristics. Production rates will be developed from published studies of operations that were conducted under circumstances applicable to western Montana. These sources tend to be objective and reliable in adequately comparing harvesting/processing systems.

Table 7 presents man- or machine-hour production rates for different systems under various utilization standards. A description of the type of operation listed in column 1 is:

THIN - thinning, small trees under 6 inches dbh included

CLEAR - clearcut

MULTI-PRODUCT (M-P) - whole tree logging with multiple products (sawlog, post or pole, and residue) recovered

LOG - conventional logging where trees were limbed and bucked at the stump and only sawlogs removed

FUEL - tree tops and branches are logged in the woods

Table 7.
Hourly Production Rates and Unit Costs

Data Source	Type Operation	Fall & Buck	Feller-Buncher	Rubber Tire Skidder	Crawler Skidder	Small Skyline
1	Multi-Prod. (Fuel Data)	5.9 Tree/hr 2.65 BDU/hr $3.49/BDU /hr	--	3.9 Tree 5.0 BDU $3.89/BDU	2.7 Tree 3.92 BDU $5.19/BDU	9.5 Tree 8.57 BDU $8.55/BDU
2	Post & Pole Clear	54 Trees/hr 2.42 CCF/hr*	--	30 Trees .994 CCF $10.18/CCF	27.3 Trees .063 CCF $15.70/CCF	--
3	Multi-Prod. Thin	39.0 Trees/hr	78.5 Trees	29.4 Trees 20.3 Trees	--	--
4	Log	$13.50/CCF $16.65	Large Small		$14.26/CCF $17.59	$12.72/CCF $15.69
5	Multi-Prod. Thin	121 PC/hr 3.49 CCF/hr	84 Trees 78 Trees	214 PC <6" DBH 271 PC 43 PC 6-15" 54 PC >16"	--	
6	Log-Fuel	--	53.4 Tree 73.4 Tree	35.0 Ton	--	--
7	Log-Clear	--	11.02 Tree 97.3 Tree	54.1 Tree 52.4 Tree	--	--
Mean Thin Oper.		85 Tree	80 Tree	200 Tree	70 Tree	
Mean Log Oper.		14 Tree	60 Tree	47 Tree	40 Tree	
Mean Multi-Prod (M.P.)		16 Tree	60 Tree	60 Tree	48 Tree	

Citations from Table 7:

[a]CCF = Cunit = 100 cubic feet solid wood.

[1]Johnson & Arkills, 1975
[2]Host & Schlieter, 1978
[3]Host & Lowery, 1983
[4]USDA-FS, 1988
[5]Goetz, 1982
[6]Mandzak, Milner, & Host, 1983
[7]Host, 1981

Fall & Buck-Buncher are widely used terms for different stages of logging process.

Although the limited number of studies listed in table 7 does not describe all possible situations, it does provide a basis for comparison. It is important to stress that tree size affects not only productivity, but also the value of products recovered. Precommercial thinnings, even though they are often marginal operations, provide a large proportion of fuel material relative to other products. Thus, they are a potentially important source for biomass fuel. Commercial thinnings and multi-product operations produce fuel from material that would otherwise not be utilized.

Some important factors regarding production should be emphasized from the studies listed in table 7. The most successful thinning operations have been conducted by a rancher-logger, who uses modified farm tractors for skidding. Production is comparable to the more expensive conventional log skidders (Goetz 1982). Another study demonstrated that, "other factors being similar," limbing and bucking on the landing produced 2.1

times as many pieces per hour as limbing and bucking at the stump (Host and Lowery 1983). This finding is particularly significant for those operations that process large numbers of small trees. Whole-tree logging operations are favored because of the efficiencies gained processing trees on the landing. Also, Johnson and Arkills (1975) determined that sawlog yarding and skidding production are not significantly reduced by extracting forest residues (tree tops, cull logs, and dead trees) at the same time. This conclusion suggests that extraction costs may not be relevant when residue is being processed at the landing--the material gets a "free ride." However, felling and yarding production data are necessary to determine the required processing capacity on the landing.

Because residue recovery to the landing can be cost-effective, landing operations are critical for evaluating fuel recovery economics. Based on table 7, table 8 shows estimates of the residue volumes that are delivered to the landing for different types of operations. As expected, thinning operations produce the highest residue volume because residues comprise a higher percentage of the total material delivered to the landing. The fuel produced has a large wood component that can amount to as much as 60 percent (Arola and Host, 1976). This is a superior fuel material. The conventional logging operation utilizes the tree only to a 6-inch top dib, while the multi-product operation utilizes the whole tree. The multi-product rate is higher than the conventional logging rate because whole-tree skidding results in fewer individual pieces moved to the landing.

Table 8.

Residue Volumes to Landing

DERIVATION OF HOURLY RESIDUE DELIVERY

Operation	Trees/ Hour	Volume/ Tree (ft^3)	Total Volume (ft^3)	Residue Volume (ft^3)	Green Weight (ton)	Bone-Dry Units (BDU)
Thin--						
Pre-Comm.	200	1.17	234	234	5.3	2.9
Comm.	92	5.19	477	180[a]	4.1	2.2
Logging	47	15.76	741	0	0	0
M-P[b]	60	18.12	1087	142	3.2	1.8

[a] Residue volume = 63 ft^3 from merchantable trees plus 1/2 pre-commercial volume.

[b] M-P = Whole tree, multi-product--6" top DIB
BDU @ 50% MC = $\frac{2400\# \times 1.5}{2000\#}$ = 1.8 ton green

PRODUCTION COST

Table 9 lists the productivity of different-sized Morbark chippers.[a] They have the advantage of portability. They also have the disadvantage in sawlog operations of being too small (11.5- inch maximum diameter tree) to process cull logs and snags. Many operators use the Model 22 because it can process multiple small stems at one time. However, production, particularly on the larger machines, is often limited by lack of raw material or landing space.

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[a] Morbark chippers have been used for estimating processing costs because they are the most widely used in western Montana. They also have the widest range of sizes for comparison purposes.

Table 9.

In-Woods Fuel Chipping Costs

MORBARK CHIPPERS

Model	12	20	22	27,30
Sample Number	8	1	6	2
BDU/Hr-x	7.9	11.9	16.3	34.4
Range	3.7-11.9	--	8.8-34.5	13.4-55.5
$/BDU[a]-x	5.42	3.80	3.45	3.05
Range	3.67-7.39	--	1.54-5.91	1.26-4.84
Labor[b] $/BDU	1.88	1.23	0.91	0.43
Total $/BDU	7.30	5.03	4.36	3.48

[a] Production data have been accumulated with limited piece size information. Dollar costs have been adjusted to 1988 dollars by applying CPI index changes. Actual production rates are low because of inability to keep in-feed volume up to machine capacity.

[b] Wages = $9.00 + 62% Overhead = $14.58/Hr.
1 BDU = 2,400 pounds, bone dry.

As mentioned previously, residue utilization could reduce other costs associated with logging. For example, a slash reduction fee of $6.00 per thousand board feet is collected by the Department of State Lands for all timber removed from state and private land in Montana. Utilizing slash for fuel automatically reduces the hazard, and the lower slash reduction fee could help offset residue processing costs. In addition, the ever-present fire hazard from slash is negated. On federal lands a slash reduction fee is often included in the stumpage rate determination. Here again, a reduction in total logging cost can result from utilizing residue.

Revenues are critical for evaluating the feasibility of these different operations. Fuel prices, FOB producer's site, are set by the buyer. That is, the producer negotiates a price allowing for loading and hauling costs. Since the location of thinning sites and road standards seriously affect haul rates, no discussion of revenues for in-woods operations has been included. Each operation is a separate situation that must be evaluated accordingly. One successful fuel producer does his own hauling, so his price includes hauling.

LUMBER OPERATIONS

Residues in a lumber mill are a nuisance, and owners do not accurately measure by-products that have little or no market value. However, data from these sources are available to estimate residue recovery ratios. First, the Bureau of Business and Economic Research (BBER) at the University of Montana monitors the forest products industry by means of quarterly surveys. Second, the U.S. Forest Service collects annual cost-revenue information from participating lumber mills, including data on lumber by-products. The by-products consist of sawdust, planer shavings, and hog fuel that includes bark. Third, a random-length sawmill in western Montana conducted an in-house evaluation of residues generated. These sources will be used to estimate a residue/lumber recovery ratio.

SOURCE	BDU/MBL Lumber Tally Bark	 By-Product*
Keegan and Jackson, Aber 1985	.301	---
USFS, Region 1, 1988	---	.778
Random-Length Mill	.352	.690

* By-Product does not include pulp chips.

The figures from the three sources correlate reasonably well. An average recovery ratio of 0.326 will be used in this analysis. Assuming an annual lumber production of 1.3 billion board feet for Montana, 423.8 million BDU of bark is generated by sawmills in the state.[9] The Forest Service survey also provides data to estimate the cost-revenue relationship for by-products.[10] The estimates for random-length mills alone and all mills are:

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[9] Keegan and Fong (1987) have determined that 74 percent of the unutilized fine residue and bark generated in western Montana (continued...)

By-Product	Random Length Mill	All Lumber Mills (with studmills)
Cost - $/BDU	$2.05	$1.92
Revenue - $/BDU	5.96	4.08
Net Revenue - $/BDU	3.91	2.16

Higher net revenue for random-mills may result from more high value by-products, namely shavings and sawdust.

Mill residues are accumulating in western Montana, despite the fact that the Stone Container Corporation purchases about 60 percent of the fuel stockpiled at chip suppliers. The net revenue data clearly suggests that the mills would sell more if they could.

DISCUSSION OF RESULTS

Table 1 listed heat values for bark of selected tree species in western Montana. The heat values will vary somewhat because bark components are different depending on location in the tree, growing site, and degree of rot or decomposition.

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[9] (...continued) consisted of bark in 1986. The other component of unused residues in that area was sawdust.

[10] Because the by-product category is not subdivided into bark, sawdust, and shavings, it is necessary to consider them all as one item. It is reasonable to assume that shavings and sawdust have a higher value than bark, and thus, some distortion is inevitable. Distortions also exist in the cost of production, because debarking costs are generally allocated to sawmill or boilerplant operation.

Table 10 summarizes fuelbark production rates and costs from the various sources. The most efficient processing takes place in lumber mills and satellite chipping plants. Although in-woods production is more costly, benefits derived from slash disposal, regeneration, and aesthetics have not been included in the cost evaluation. In-woods fuel operations can definitely provide an alternative source if the need arises.

Table 10.

Production/Cost Summary[a]

Operation	Hourly Production BDU	Cost/ BDU $	Cost/ Million BDU $
Greenough Lumber	0.52	11.24	0.50
Satellite Chipping	7.50	3.72	0.17
In-Woods			
Precommercial	2.9	7.30	0.33
Commercial	2.2	7.30	0.33
Multi-Product	1.8	5.03	0.22
Lumber Mill			
All	NA	1.92	0.09
Random-Length	NA	2.05	0.09

[a] Assumes a zero cost for raw material

With an average heat value of 22.32 MM BTUs per BDU (table 1) and a burning efficiency of 70 percent, the sawmill residues can produce 1 MM BTU of heat for 13 cents of raw material. This is very favorable when compared to other fuels. For instance, neglecting the differences in burning efficiencies, handling costs, etc., the comparative cost per MM BTU of heat is:

	COST/ MM BTU $
Mill residue- @ \$2.00/BDU, 22.32 BTU/BDU	0.09
Natural gas- @ \$3.00/Mft³, 1,000 BTU/ft³	3.00
#2 Oil- @ \$.52/gal., 136,000 BTU/gal.	3.82
#6 Oil- @ \$.48/gal., 150,000 BTU/gal.	3.20
Bituminous coal- @ \$50/ton, 13,000 BTU/#	1.92

Some caution must be used when looking at the comparisons! The difference in cubic volumes per MM BTUs will cause higher handling costs for wood residues. Energy conversion equipment will also be a greater expense than with any of the other fuels.

The most obvious deterrent to fuelbark utilization is the lack of adequate markets and the cost of competing fuels. However, it is apparent that consideration of disposal costs can positively affect sawmill co-generation economics of using fuelbark. An example is Champion Building Products in Libby, Montana. Further studies are needed to:

1. Improve the date base for fuelbark production volumes and costs; broaden the spectrum of data pertaining to differences in log sizes and species. Until fuelbark attains a positive market value, it will be necessary to rely on indirect estimates which can be questionable.

2. Recognition of social costs of not fully utilizing mill residues can impact the pressure for utilization. For instance, disposed in large piles wood wastes can pollute groundwater;

spontaneous combustion in piles is an expensive risk. (Turning over the material in the utilization process tends to reduce this risk.) Recognition of disposal costs will force utilization of bark residues at lumber and plywood mills. A logical direction for utilization will be for fuel either in-plant or sold in an open market.

3. The impetus to burn bark will lead to improved burning technology. This will further enhance the marketability of fuelbark. Environmental protection rules may prohibit slash burning on logging operations. This could increase the supply of biomass fuels and thereby stabilize a larger supply level.

The shortening of planning horizons in the forest products industry caused by environmental pressures seriously limits the number of operators who can afford to study the problem adequately. Hence, it is necessary to seek help elsewhere. That is, if the needed studies of this problem are to occur, help from programs like the Montana DNRC has underway can perform a critical function.

APPENDIX A

FUELBARK HEAT VALUES OF VARIOUS WESTERN SOFTWOODS

SPECIES	BTU/lb (Wet Basis)		ASH % (Wet Basis)		MOISTURE CONT. % (Wet Basis)	
	X	S	X	S	X	S
Yellow Pine-2	9168	22	2.1	0.1	5.8	0.1
Bull Pine-1	9097	56	2.4	0.1	6.3	0.0
Bull Pine-2	9530	29	2.4	0.0	2.2	0.0
LPP-1	9362	10	2.9	0.05	7.6	0.1
LPP-2	9718	25	5.0	0.01	6.3	0.0
DF-1	8542	128	5.9	0.10	6.0	0.11
DF-2	9571	145	3.1	0.05	5.9	0.05
WL-1	8633	35	3.1	0.05	6.3	0.15
WL-2	8543	137	2.1	0.1	6.3	0.0
ES-1	8826	101	4.9	0.7	5.7	0.0
GF-1	9520	25	4.3	0.05	5.3	0.11
RC-1	8494	13	5.2	0.0	6.0	0.01

Suffix 1 = thin bark, 2 = thick bark.

X = Mean
S = Standard Deviation
LPP = Lodgepole Pine
DF = Douglas Fir
WL = Western Larch
ES = Engelmann Spruce
GF = Grand Fir
RC = Red Cedar

BIBLIOGRAPHY

Arola, R. A., and J. R. Host. 1976. Debarking chipped logging residues. Research Paper INT-179. Ogden, Utah: Intermountain Forest and Range Experiment Station, USDA, Forest Service.

Brown, H. P., A. J. Panshin, and C. C. Forsaith. 1949. Textbook of wood techology, Vol. I. New York: McGraw Hill Book Co.

Brown, L. F., L. S. Craig, and P. Buscaglea. 1984. Evaluating double-entry logging for forest residue recovery in southwestern Oregon. Grants Pass, Ore.: Larry Brown & Associates.

Brown, S. L., and J. A. Bergvall. 1986. Small tree harvest system recovering residue for energy. Olympia, Wash.: State of Washington Department of Natural Resources.

Chamberlain, N., and A. H. Meyer. 1950. Bark volume in cordwood. Technical Applications of Pulp and Paper Institute, Vol. 33 (11): 554-555.

Faurot, J. L. 1977. Estimating merchantable volume and stem residue in four timber species: Ponderosa pine, Lodgepole pine, Western larch, Douglas-fir. Research Paper INT-196. Ogden, Utah: USDA, Forest Service.

Gardner, R. B., and D. F. Gibson. 1975. Improved utilization and disposal of logging residues. In transactions of the American Society of Agricultural Engineers, Vol. 18 (5).

Goetz, H. 1980. Whole tree chipping trials in the Blackfoot Valley. Paper No. PNW-80-406. St. Joseph, Michigan: American Society of Agricultural Engineers.

__________. 1982. Timber thinning project for utilization of residue. Missoula, Montana: Montana Forest and Conservation Experiment Station.

__________. 1987. Productivity of alternative harvesting systems in small timber. In process management of small-stem stands of lodgepole pine. General Technical Report INT-237. Ogden, Utah: USDA, Forest Service.

Gonsior, M. J., and J. M. Mandzak. 1987. Mechanized systems for harvesting small-stem lodgepole pine in mountainous terrain. In process management of small-stem lodgepole pine. General Technical Report INT-237. Ogden, Utah: USDA, Forest Service.

Haygreen, J. G., and J. L. Bowyer. 1982. Forest products and wood science, an introduction. Ames, Iowa: Iowa State University Press.

Host, J. R. 1979. Upgrading intermountain logging residues by chip debarking. In Process Chipping in the Woods Symposium. Corvallis, Ore.: Oregon State University.

__________. 1981. A preliminary report for production rates for thinning second growth ponderosa pine. Unpublished study report.

Host, J. R., and D. P. Lowery. 1970. Portable debarking and chipping machines can improve forestry practices. Research Note INT-112. Ogden, Utah: Intermountain Forest and Range Experiment Station.

__________. 1983. Salvage and thinning operations in second growth Ponderosa Pine stands. Research Paper INT-311. Ogden, Utah: Intermountain Forest and Range Experiment Station.

Host, J. R., and J. Schlieter. 1978. Low-cost harvesting systems for intensive utilization in small-stem lodgepole pine stands. Research Paper INT-201. Ogden, Utah: Intermountain Forest and Range Experiment Station.

Jackson, T. P., R. P. Withycombe, and C. E. Keegan. 1984. Estimating the costs of recovering forest residue in the northern Rocky Mountains. Missoula, Montana: University of Montana, Bureau of Business and Economic Research.

Johnson, L. R., and J. Arkills. 1975. Integration of whole tree chipping with a traditional sawlog operation. Transactions of the American Society of Agricultural Engineers, Vol. 19 (5).

Keegan, C. E., and T. Fong. 1987. Mill residue availability in Montana. Missoula, Montana: University of Montana, Bureau of Business and Economic Research.

Keegan, C. E., and T. P. Jackson. 1985. Mill residue availability in the Inland Empire. Forest Products Journal, Vol. 35 (10).

Krier, J. P., and B. H. River. 1968. Bark residues: a model for quantitative determination. Bulletin 35. Missoula, Montana: Montana Forest and Conservation Station.

Laird, P. 1988. Personal conversations. Missoula, Montana.

Lambert, M. B., and J. O. Howard. 1987. Harvesting overstocked stands of small diameter trees, Report No. 4: Cost and productivy of new felling and forwarding equipment. Report to the U.S. Department of Energy, Bonneville Power Administration. Portland, Ore.: Pacific Northwest Forest and Range Experiment Station, USDA, Forest Service.

Lowery, D. P., J. P. Krier, and J. R. Host. 1971. Bark residues in western Montana. Research Note INT-140. Ogden, Utah: Intermountain Forest and Range Experiment Station, USDA, Forest Service.

MacIntosh, J. E., and A. W. J. Sinclair. 1988. Economic feasibility of satellite chipping yards in Alberta. Special Report No. SR-53. Vancouver, B.C.: Forest Engineering Research Institute of Canada.

Mandzak, J. M., K. S. Milner, and J. R. Host. 1983. Production and product recovery for complete tree utilization in the northern Rockies. Research Paper INT-306. Ogden, Utah: Intermountain Forest and Range Experiment Station.

Meyer, A. H. 1946. Bark volume determination. Journal of Forestry 44(12): 1067-70.

Thayer, T. 1979. Personal conversation. Missoula, Montana.

USDA, Forest Service. 1955. Wood handbook. Agricultural Handbook No. 72. Madison, Wisconsin: Forest Product Laboratory.

__________. 1974. Wood handbook, revised. Madison, Wisconsin: Forest Product Laboratory.

__________. 1988. Region I timber sale appraisal handbook. Missoula, Montana.